AF# / 2811

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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent Application of:

Jeong-kwan Lee, et al.

Application No.: 09/982,086 Group Art Unit: 2811

Filed: October 19, 2001 Examiner: Samuel A. Gebremariam

For: MICRO-LENS BUILT-IN VERTICAL CAVITY SURFACE EMITTING LASER

SUPPLEMENTAL APPEAL BRIEF UNDER 37 C.F.R §§ 1.191 AND 1.192 FOLLOWING THE NOTICE OF NON COMPLIANT APPEAL BRIEF, MAILED JUNE 30, 2005

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Commissioner for Patents
PO Box 1450
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Sir:

Pursuant to the Appellant's earlier filed Notice of Appeal on February 16, 2005, Appellant hereby appeals to the Board of Patent Appeals and Interferences from the final rejection mailed November 16, 2004.

Appellant submits this Appeal Brief in triplicate as required by 37 C.F.R. §1.192(a) along with the filing fee of $500.00 set forth in 37 C.F.R. §1.17(c).

I. Real Party in Interest

Pursuant to 37 C.F.R. §1.192(c)(1), due to the assignment executed on October 23, 2001 by the inventors Jeong-kwan LEE and Jae-hoon LEE and recorded in the United States Patent and Trademark Office at Reel 12474, Frame 0303, the real party in interest is as follows:

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II. Related Appeals and Interferences

Pursuant to 37 C.F.R. §1.192(c)(2), although the real party in interest has other appeals

and interferences, none of the other pending appeals and interferences is believed to directly affect or be directly affected by, or have any bearing upon the decision of the Board of Patent Appeals and Interferences in this appeal.

III. Status of Claims

Pursuant to 37 C.F.R. §1.192(c)(3), claims 1 through 64 are pending in this application at the filing of this Appeal Brief. No claims stand allowed, and claims 1-64 stand finally rejected. Claims 1, 6, 12, 17, and 23 are independent claims, and claims 2-5, 7-11, 13-16, 18-22, and 24-64 are dependent claims.

Claims 1 through 64 were originally filed in the application. In the Amendment filed October 16, 2002, claims 23, 24, and 54 were amended. In the Response and Request for Reconsideration filed under 37 C.F.R. §1.116 on March 21, 2003, entered pursuant to a Request for Continued Examination (RCE) filed April 23, 2003, claims 1, 6, 12, 17, and 23 were amended. In the Amendment filed September 23, 2003, claims 1, 12, 23, 36, and 54 were amended. In the Amendment filed March 1, 2004, claims 1, 6, 12, 17, and 23 were amended. Two Requests for Reconsideration were then filed on August 18, 2004 and January 14, 2005, respectively.

In view of the final Office Action mailed November 16, 2004, claims 1-64 stand finally rejected. This Appeal Brief is an appeal of the finally rejected claims 1-64.

IV. Status of Amendments

Pursuant to 37 C.F.R. §1.192(c)(4), no amendments have been filed since the final Office Action of November 16, 2004.

Pursuant to 37 C.F.R. §1.192(c)(9), a copy of the claims involved in the appeal is included in their present condition is included in Appendix A.

V. Summary of the Invention

Pursuant to 37 C.F.R. §1.192(c)(5), the present invention is directed to a micro-lens built-in vertical cavity surface emitting laser (VCSEL) in which a micro-lens is formed on a laser beam

emitting surface of the VCSEL. More particularly, the present invention is directed to a micro lens built-in VCSEL capable of emitting a parallel light beam.

As such, as shown in FIG. 2, the claimed micro-lens built-in vertical cavity surface emitting laser (VCSEL) comprises a substrate, a lower reflector formed on the substrate, an active layer formed on the lower reflector, generating light by a recombination of electrons and holes, an upper reflector formed on the active layer comprising a lower reflectivity than that of the lower reflector, a micro-lens, a lens layer formed on the upper reflector with a transparent material transmitting a laser beam, the lens layer comprising the micro-lens, an upper electrode formed above the upper reflector, and a lower electrode formed underneath the substrate.

Specifically, the micro lens is disposed in a window region of the lens layer, which, as shown in FIGs. 2, 5, and 6, appears as a depression from a surface of the lens layer with a convex shaped bottom surface. Thus, the convex surface is a single surface having an arch extending through the entire window region. Further, the laser beam is emitted through the convex surface so as to collimate the laser beam across the entire window region. *See FIG. 2.*

Further, the claimed micro-lens may be disposed in a window region through which the laser beam is emitted to collimate the laser beam across the entire window region, wherein the micro-lens comprises an arch extending through the entire window region and wherein the window region comprises a maximum width smaller than a size of light generated in the active layer emitted towards the window region, satisfying a Fraunhofer diffraction condition, where the Fraunhofer diffraction condition occurring in the window region is offset by a focusing power of the micro-lens.

VI. Issues

1. Whether claims 1-3, 5-9, 11-20, and 22-64 are patentable under 35 U.S.C. §103(a) over admitted prior art, Jiang et al (U.S. Patent No. 5,438666 and hereinafter referred to as "Jiang") in view of Webb (U.S. Patent No. 6,051,848 and hereinafter referred to as "Webb").

2. Whether claims 4, 10, and 21 are patentable under 35 U.S.C. §103(a) over admitted prior art, Jiang, Webb, and in view of Peake et al. (U.S. Patent No. 6,122,109 and hereinafter referred to as "Peake").

VII. <u>Grouping of Claims</u>

Pursuant to 37 C.F.R. §1.192(c)(7), the claims are grouped as follows:

1. All claims stand or fall together.

VIII. <u>Arguments</u>

1. Claims 1-3, 5-9, 11-20, and 22-64 are patentably distinguishable over the combination of the admitted prior art, Jiang and Webb.

To establish a *prima facie* case of obviousness, three basic criteria must be met. First, there must be some suggestion or motivation, either in the references themselves or in the knowledge generally available to one of ordinary skill in the art, to modify the reference or to combine reference teachings. Second, there must be a reasonable expectation of success. Finally, the prior art reference (or references when combined) must teach or suggest all the claim limitations. The teaching or suggestion to make the claimed combination and the reasonable expectation of success must both be found in the prior art, not in applicant's disclosure. See MPEP § 2143 citing *In re Vaeck*, 947 F.2d 488, 20 USPQ2d 1438 (Fed. Cir. 1991).

Moreover, the mere fact that references <u>can</u> be combined or modified does not render the resultant combination obvious unless the prior art also suggests the desirability of the combination. *In re Mills*, 916 F.2d 680, 16 USPQ2d 1430 (Fed. Cir. 1990). Similarly, if the proposed modification would render the prior art invention being modified unsatisfactory for its intended purpose, then there is no suggestion or motivation to make the proposed modification. *In re Gordon*, 733 F.2d 900, 221 USPQ 1125 (Fed. Cir. 1984). See MPEP § 2143.

<u>A. Regardless of the presence of the admitted prior art, the references to Jiang and Webb cannot and should not be combined as suggested.</u>

By way of review, the independent claims generally recite a micro-lens built-in vertical cavity surface emitting laser (VCSEL). The micro-lens comprises a substrate, a lower reflector formed on the substrate, an active layer formed on the lower reflector, generating light by a recombination of electrons and holes, an upper reflector formed on the active layer comprising a

lower reflectivity than that of the lower reflector, a micro-lens disposed in a window region and comprising a single convex surface having an arch extending through the entire window region through which the laser beam is emitted to collimate the laser beam across the entire window region, a lens layer formed on the upper reflector with a transparent material transmitting a laser beam, the lens layer comprising the micro-lens, an upper electrode formed above the upper reflector excluding the window region, and a lower electrode formed underneath the substrate.

Jiang, on the other hand, describes a diffractive planar lens element 44 etched into the uppermost surface of the second stack 22 and is capable of focusing and/or collimating laser emission 12 without the necessity of an external lens or lens array. *See Jiang at column 6, lines 46-63.* Indeed, according to Jiang, external lenses or lens arrays are often quite bulky and not lent to small overall package sizes. Using the VCSEL substrate as a lens to which etching methods are applied overcomes the problem of these bulky external lenses and lens arrays. *See id. at column 1, lines 50-66.*

Webb teaches a method of forming a lens structure that results in, quite simply, a bulky external lens relative to the die 10. *See Webb, FIGS. 1-6.* According to Webb, the lens pattern 22 is formed by encapsulation of the die 10 (e.g. a VCSEL) within a mold material 20. Before the mold material 20 hardens, a portion of the mold material 20 is shaped to form the lens pattern 22. *See id. at column 2, lines 37-49.*

Nevertheless, the Examiner has suggested that, "it would have been obvious to one of ordinary skill in the art . . . to modify the lens structure [44] of Jiang by forming a single lens having an arch extending through the entire window region as taught by Webb in order to reduce the processing step of forming a single lens by etching." Applicants respectively disagree.

As is apparent from a comparison of Jiang and Webb, available evidence relating to the features of the references in question refutes the suggestions of the Examiner. First, the lens element 44 of Jiang fits entirely within the uppermost surface of the VCSEL 10. Second, the VCSEL 10 of Jiang appears to correspond in relative size to the die 10 of Webb. Third, Webb teaches that the package 18 and the lens pattern 22, is an order of size larger than the die 10. *See Webb at FIGs. 1-4.* Thus, by association, the package 18 must also be an order of size larger than the VCSEL 10 of Jiang. This size difference is indeed so large that the Jiang VCSEL 10, and certainly the lens element 44 which occupies only a small portion of the VCSEL 10,

would be dwarfed by package 18 and lens pattern 22 of Webb. *See Webb at FIGS. 1-6 and Jiang at FIG. 1 (noting the relative size of the mold material 20 and the die 10 of Webb in comparison with the VCSEL 10 of Jiang).*

From the above analysis it appears as though the suggested combination of Webb and Jiang would require that a relatively large structure (i.e. the lens pattern 22 of Webb) be installed within a relatively small structure (i.e. the lens element 44 of Jiang). Since the citation of the admitted prior art does not change this analysis, applicants respectfully assert that this combination is obviously flawed and, thus, a reasonable degree of success of the combination cannot be expected. Therefore, applicants further assert that the suggested combination is improper.

<u>B. The only reasonable combination of the admitted prior art, Jiang and Webb is one in which the teachings of Jiang replace the teachings of the die 10 such that the Jiang VCSEL 10 is located inside the package 18 of Webb.</u>

Applicants additionally note that even if, *arguendo*, the teachings of Jiang and Webb were to be combined, they could only be combined such that the Jiang VCSEL 10 was located inside the package 18 of Webb. This conclusion may be seen upon a review of both references and a comparison of the relative sizes of the features of each. As noted above, the Office's suggestion that a relatively large structure (i.e. the lens pattern 22 of Webb) be installed within a relatively small structure (i.e. the lens element 44 of Jiang) is flawed. Conversely, it can be seen that when the Jiang device is installed within the Webb die 10 and combined with teachings of the admitted prior art, the respective features are appropriately sized such that the combination is possible. Of course, however, applicants note that this combination is also improper for the reasons discussed below.

<u>C. Jiang specifically teaches away from the only physically reasonable combination of the admitted prior art, Jiang and Webb.</u>

Since, as noted above, Jiang discloses that, "external lenses or lens arrays are often quite bulky and not lent to small overall package sizes," and since the only reasonable

combination of the references, given the relative size differences between the Jiang and Webb devices, includes the use of the Webb teachings as an external lens that surrounds the Jiang VCSEL 10 in the same or a similar manner as the way in which the lens pattern 22 and package 18 of Webb surround the die 10, Jiang teaches away from the suggested combination.

In other words, Jiang teaches that the suggested combination is undesirable because the combination would necessarily result in the existence of a bulky external lens or lens array that would tend to have a large overall package size as opposed to a smaller one. Moreover, give the Jiang prohibition against the use of external lenses or lens arrays, the proposed combination between Jiang and Webb would render Jiang being modified such that the Jiang device is unsatisfactory for its intended purpose, providing a VCSEL having a reduced size. *See Jiang at column 1, lines 56-58.*

Since the suggested combination is undesirable, even with the addition of the teachings of the admitted prior art, and renders Jiang being modified such that the Jiang device is unsatisfactory for its intended purpose, applicants respectively assert that Jiang teaches away from the suggested combination and that, therefore, the suggestion to combine Jiang with Webb is improper.

D. The Examiner's suggested combination is insufficient to support a prima facie obviousness rejection since the suggestion combination does not teach or suggest all of the claim limitations.

Despite the above discussions, applicants understand that the Examiner may be suggesting that the lens pattern 22 of Webb provides a teaching of a lens having a similar shape as the top surface of the package 18 (i.e., a flat surface with an arch extending up and out from an inner circumference of the flat surface, as in FIG. 1 of Webb) and, further, that the shape of the lens element 44 of Jiang should be based upon that shape. Assuming, *arguendo*, that the references support such a conclusion, applicants assert that this combination fails to teach or suggest the claimed, "single convex surface having an arch extending through the entire window region."

It is again noted that the lens pattern 22 of Webb is understood to be the entire top

surface of the package 18. That is, the lens pattern 22 includes the curved portion extending from the inside circumference of the flat surface of the package 18 and the flat surface as well. *See id. at e.g. FIG. 2.* As a result, Webb does not disclose a single convex surface having an arch extending through the entire window region, as claimed.

In support of this position, applicants note that Webb does not distinguish between the lens pattern 22 and the flat area of the top surface of the package 18. Thus, one cannot infer that such a distinction exists. Nevertheless, the Advisory Action of February 8, 2005 alleged that the window region in Webb refers to only the part of the lens pattern 22 that is used to focus the light emitted from the optical transmitter (i.e., the curved portion of the lens pattern). In other words, the Office draws an improper distinction between the lens pattern 22 and the flat area of the top surface of the package 18.

Thus, it appears that the Office's position is that the curved portion of the lens pattern 22 is the only feature of Webb to be thought of as the lens pattern 22. Applicants disagree and note that Web discloses a supplemental lens system 28 having an outside surface similar to that of the lens pattern 22. Here, Webb identifies the external lens 30 as being a distinct feature of the supplemental lens system. No such distinction is made with respect to the curved portion of the lens pattern 22.

Thus, applicants conclude that Webb does not teach the distinction envisioned by the Examiner. As such, the lens pattern 22 of Webb includes not only the curved surface but also the flat surface located around the curved surface. Consequently, Webb does not provide the "single convex surface having an arch extending through the entire window region through which the laser beam is emitted," as claimed, but rather, discloses an arch that is surrounded by a flat surface extending through the entire window region. Therefore, the suggested combination of Webb and Jiang along with the admitted prior art, none of which discloses the claimed feature in question, also fails to teach or suggest the claimed feature in question.

E. Even if the lens pattern 22 of Webb only refers to the curved portion of the top surface of the package 18, such that the suggested combination teaches all of the features in question, the reasoning provided, in support of the combination, is internally inconsistent.

i. Applicants note that both Jiang and Webb teach that central portions of their respective lenses are smooth arches. Thus, even if the Examiner is correct in the assertion that the window region in Webb only refers to the arc of the lens pattern 22, consistent analysis requires that the Examiner make the same statement about the Jiang lens element 44. That is, that the window region only refers to the central arch in the lens element 44. Thus, it follows that a suggestion of a combination between Webb and Jiang means that one smooth arch is being substituted for another smooth arch and is, therefore, redundant.

ii. Furthemore, the Office has suggested that substituting the Webb lens pattern for the lens element 44 of Jiang reduces "the processing step of forming a single lens by etching." This assertion, may be true, however, it ignores the fact that the lens pattern of Webb is formed by a molding operation including injections of molding material and hardening and that such a process would then have to be repeated on a significantly smaller scale so as to achieve the same effect on the VCSEL of Jiang. It is understood that such a process would be no more effective or efficient than the etching process which is being avoided.

2. **Claims 4, 10, and 21 are patentable under 35 U.S.C. §103(a) over admitted prior art, Jiang, Webb, and in view of Peake et al. (U.S. Patent No. 6,122,109 and hereinafter referred to as "Peake").**

Given that the combination of Jiang and Webb is improper as discussed above, and since the additional references fail to cure the deficiencies of the combination of Jiang and Webb, the rejections of claims 4, 10, and 21 are believed to be overcome.

IX. Conclusion

In view of the law and facts stated herein, the Appellant respectfully submits that the Examiner has failed to cite a reference(s) sufficient to maintain the rejections of the rejected claims. Specifically, the Appellant respectfully submits that, even given the broadest reasonable interpretation, the combination of Jiang and Webb does not disclose the invention as recited in claims 1-64. For all the foregoing reasons, the Appellant respectfully submits that the cited prior art does not teach or suggest the presently claimed invention. The claims are patentable over the prior art of record and the Examiner's findings of unpatentability regarding claims 1-64 should be reversed.

The Commissioner is hereby authorized to charge any additional fees required in connection with the filing of the Appeal Brief to our Deposit Account No. 503333.

Respectfully submitted,

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X. Appendix A

1. (Previously presented) A micro-lens built-in vertical cavity surface emitting laser (VCSEL) comprising:

a substrate;

a lower reflector formed on the substrate;

an active layer formed on the lower reflector, generating light by a recombination of electrons and holes;

an upper reflector formed on the active layer comprising a lower reflectivity than that of the lower reflector;

a micro-lens disposed in a window region and comprising a single convex surface having an arch extending through the entire window region through which the laser beam is emitted to collimate the laser beam across the entire window region;

a lens layer formed on the upper reflector with a transparent material transmitting a laser beam, the lens layer comprising the micro-lens;

an upper electrode formed above the upper reflector excluding the window region; and

a lower electrode formed underneath the substrate.

2. (Previously presented) The micro-lens built in VCSEL as recited in claim 1, wherein the VCSEL satisfies a following relationship:

$$f = R \times n1/(n2 - n1)$$

where f is a distance along an optical axis from a light generating region of the active layer to a vertex of the micro-lens, R is a radius of curvature of the micro-lens, n1 is an effective refractive index of a medium on an optical path between the light generating region and the lens layer, and n2 is a refractive index of a region towards which a light is emitted through the micro-lens.

3. (Original) The micro-lens built-in VCSEL as recited in claim 1, further comprising a high-resistance region between the upper and lower reflectors relatively close to the active layer, the high-resistance region having an aperture at a center thereof through which a current flows.

4. (Original) The micro-lens built-in VCSEL as recited in claim 1, wherein the lens layer is formed of a material comprising at least one of silicon and a III-V compound semiconductor, wherein the III-V compound semiconductor comprises one of indium phosphide (InP), gallium arsenide (GaAs), indium arsenide (InAs), gallium phosphide (GaP), indium gallium phosphide (InGaP), indium gallium arsenide (InGaAs), and aluminum gallium arsenide (AlGaAs), the material comprising a relatively large bandgap to a wavelength of the laser beam so as not to absorb the laser beam.

5. (Original) The micro-lens built-in VCSEL as recited in claim 1, wherein the micro-lens is formed by diffusion-limited etching.

6. (Previously presented) A micro-lens built-in vertical cavity surface emitting laser (VCSEL) comprising:

a substrate;

a lower reflector formed on the substrate;

an active layer formed on the lower reflector generating light by a recombination of electrons and holes;

an upper reflector formed on the active layer comprising a lower reflectivity than that of the lower reflector;

a micro-lens disposed in a window region through which the laser beam is emitted to collimate the laser beam across the entire window region, wherein the micro-lens comprises an arch extending through the entire window region;

a lens layer formed on the upper reflector with a transparent material transmitting a laser beam, the lens layer comprising the micro-lens;

an upper electrode formed above the upper reflector excluding the window region; and

a lower electrode formed underneath the substrate,

wherein the window region comprises a maximum width smaller than a size of light generated in the active layer emitted towards the window region, satisfying a Fraunhofer diffraction condition, where the Fraunhofer diffraction condition occurring in the window region is offset by a focusing power of the micro-lens.

7. (Original) The micro-lens built-in VCSEL as recited in claim 6, wherein the maximum width of the window region D and a focal length *f* of the micro-lens satisfy a relation:

$$D = \sqrt{2 \times 1.22\lambda f}$$

where λ is a wavelength of the laser beam emitted from the VCSEL.

8. (Original) The micro-lens built-in VCSEL as recited in claim 6, further comprising a high-resistance region between the upper and lower reflectors, relatively close to the active layer, the high-resistance region comprising an aperture at a center thereof through which a current flows, the aperture of the high-resistance region comprising a maximum width greater than or approximately equal to the maximum width of the window region.

9. (Original) The micro-lens built-in VCSEL as recited in claim 7, further comprising a high-resistance region between the upper and lower reflectors, relatively close to the active layer, the high-resistance region comprising an aperture at a center thereof through which a current flows, the aperture of the high-resistance region comprising a maximum width greater than or approximately equal to the maximum width of the window region.

10. (Original) The micro-lens built-in VCSEL as recited in claim 4, wherein the lens layer is formed of a material comprising at least one of silicon and a III-V compound semiconductor, wherein the III-V compound semiconductor comprises one of indium phosphide (InP), gallium arsenide (GaAs), indium arsenide (InAs), gallium phosphide (GaP), indium gallium phosphide (InGaP), indium gallium arsenide (InGaAs), and aluminum gallium arsenide (AlGaAs), the material comprising a relatively large bandgap to a wavelength of the laser beam so as not to absorb the laser beam.

11. (Original) The micro-lens built-in VCSEL as recited in claim 4, wherein the micro-lens is formed by diffusion-limited etching.

12. (Previously presented) A micro-lens built-in vertical cavity surface emitting laser (VCSEL) comprising:

a micro-lens disposed in a window region and comprising a single convex surface having an arch extending through the entire window region through which a laser beam is emitted to collimate the laser beam across the entire window region;

a substrate comprising a transparent material transmitting the laser beam, the substrate comprising the micro-lens;

a lower reflector formed on the substrate;

an active layer formed on the lower reflector, generating light by recombination of electrons and holes;

an upper reflector formed on the active layer comprising a higher reflectivity than that of the lower reflector;

an upper electrode formed on the upper reflector; and

a lower electrode formed on a portion of the substrate excluding the window region through which the laser beam is emitted.

13. (Original) The micro-lens built in VCSEL as recited in claim 12, wherein the VCSEL satisfies a following relationship:

$$f = R \times n1/(n2 - n1)$$

where *f* is a distance along an optical axis from a light generating region of the active layer to a vertex of the micro-lens, R is a radius of curvature of the micro-lens, n1 is an effective refractive index of a medium on an optical path between the light generating region and the lens layer, and n2 is a refractive index of a region towards which a light is emitted through the micro-lens.

14. (Original) The micro-lens built-in VCSEL as recited in claim 12, further comprising a high-resistance region between the upper and lower reflectors relatively close to the active

layer, the high-resistance region having an aperture at a center thereof through which a current flows.

15. (Original) The micro-lens built-in VCSEL as recited in claim 12, wherein the lens layer is formed of a material comprising at least one of silicon and a III-V compound semiconductor, wherein the III-V compound semiconductor comprises one of indium phosphide (InP), gallium arsenide (GaAs), indium arsenide (InAs), gallium phosphide (GaP), indium gallium phosphide (InGaP), indium gallium arsenide (InGaAs), and aluminum gallium arsenide (AlGaAs), the material comprising a relatively large bandgap to a wavelength of the laser beam so as not to absorb the laser beam.

16. (Original) The micro-lens built-in VCSEL as recited in claim 12, wherein the micro-lens is formed by diffusion-limited etching.

17. (Previously presented) A micro-lens built-in vertical cavity surface emitting laser (VCSEL) comprising:

a micro-lens disposed in a window region through which a laser beam is emitted to collimate the laser beam across the entire window region, wherein the micro-lens comprises an arch extending through the entire window region;

a substrate comprising a transparent material transmitting the laser beam, the substrate comprising the micro-lens;

a lower reflector formed on the substrate;

an active layer formed on the lower reflector, generating light by recombination of electrons and holes;

an upper reflector formed on the active layer comprising a higher reflectivity than that of the lower reflector;

an upper electrode formed on the upper reflector; and

a lower electrode formed on a portion of the substrate excluding the window region through which the laser beam is emitted,

wherein the window region comprises a maximum width smaller than a size of the light generated in the active layer and emitted towards the window region, satisfying a Fraunhofer

diffraction condition, where the Fraunhofer diffraction condition occurring in the window region is offset by a focusing power of the micro-lens.

18. (Original) The micro-lens built-in VCSEL as recited in claim 17, wherein the maximum width of the window region D and a focal length *f* of the micro-lens satisfy a relation:

$$D = \sqrt{2 \times 1.22 \lambda f}$$

where λ is a wavelength of the laser beam emitted from the VCSEL.

19. (Original) The micro-lens built-in VCSEL as recited in claim 17, further comprising a high-resistance region between the upper and lower reflectors positioned relatively close to the active layer, the high-resistance region comprising an aperture at a center thereof through which a current flows, where the aperture of the high-resistance region comprises a maximum width greater than or approximately equal to the maximum width of the window region.

20. (Original) The micro-lens built-in VCSEL as recited in claim 18, further comprising a high-resistance region between the upper and lower reflectors positioned relatively close to the active layer, the high-resistance region comprising an aperture at a center thereof through which a current flows, where the aperture of the high-resistance region comprises a maximum width greater than or approximately equal to the maximum width of the window region.

21. (Original) The micro-lens built-in VCSEL as recited in claim 17, wherein the lens layer is formed of a material comprising at least one of silicon and a III-V compound semiconductor, wherein the III-V compound semiconductor comprises one of indium phosphide (InP), gallium arsenide (GaAs), indium arsenide (InAs), gallium phosphide (GaP), indium gallium phosphide (InGaP), indium gallium arsenide (InGaAs), and aluminum gallium arsenide (AlGaAs), the material comprising a relatively large bandgap to a wavelength of the laser beam so as not to absorb the laser beam.

22. (Original) The micro-lens built-in VCSEL as recited in claim 18, wherein the micro-lens is formed by diffusion-limited etching.

23. (Previously presented) A micro-lens built-in vertical cavity surface emitting laser (VCSEL), comprising:

a micro-lens integrally formed on a laser beam emitting surface of the VCSEL and comprising a single convex surface disposed in a window region through which a light beam is emitted to collimate the light beam across a window region to emit a parallel light beam, wherein the single convex surface comprises an arch extending through the entire window region;

a lens layer comprising the micro-lens and formed on the laser beam emitting surface of the VCSEL; and

an upper electrode formed on a portion of the lens layer excluding the window region.

24. (Previously presented) The micro-lens built-in VCSEL as recited in claim 23, further comprising:

a substrate;

a lower electrode formed underneath the substrate;

a lower reflector;

an active layer comprising a light generating region; and

an upper reflector comprising a relatively lower reflectivity than that of the lower reflector, wherein the window region is defined by the upper electrode and the micro-lens.

25. (Original) The micro-lens built-in VCSEL as recited in claim 24, wherein the first focal point of the micro-lens is positioned in the light generating region of the active layer, so that the light beam generated in a narrow light generating region is incident on and condensed by the micro-lens, and is emitted as the parallel light beam.

26. (Original) The micro-lens built-in VCSEL as recited in claim 24, further comprising:

a high-resistance region between the upper and lower reflectors relatively close to the active layer, the high-resistance region having an aperture at a center thereof through which a current flows comprising a maximum width greater than or approximately equal to the maximum width of the window region.

27. (Original) The micro-lens built-in VCSEL as recited in claim 26, wherein the aperture is small where the current applied through the upper electrode passes a region on the active layer and the light beam is generated in a dot-sized region of the active layer.

28. (Original) The micro-lens built-in VCSEL as recited in claim 23, wherein the micro-lens lies along a central optical axis of the light beam emitted from the VCSEL.

29. (Original) The micro-lens built-in VCSEL as recited in claim 24, wherein the lower reflector, the active layer, and the upper reflector are sequentially stacked on the substrate.

30. (Original) The micro-lens built-in VCSEL as recited in claim 24, wherein the substrate is formed of a semiconductor material comprising n-doped gallium arsenide (GaAs), aluminum gallium arsenide (AlGaAs), indium arsenide (InAs), indium phosphide (InP), gallium phosphide (GaP), indium gallium phosphide (InGaP), indium gallium arsenide (InGaAs), or gallium phosphide (GaP), the material comprising a relatively large bandgap to a wavelength of the laser beam so as not to absorb the laser beam.

31. (Original) The micro-lens built-in VCSEL as recited in claim 24, wherein the lower reflector and the upper reflector are formed of alternating semiconductor compounds comprising different refractive indexes.

32. (Original) The micro-lens built-in VCSEL as recited in claim 24, wherein the substrate is doped with n-type impurities, the lower reflector is doped with the same n-type impurities and the upper reflector is doped with p-type impurities.

33. (Original) The micro-lens built-in VCSEL as recited in claim 24, wherein the active layer is formed of GaAs, AlGaAs, InGaAs, InGaP and/or AlGaAsP according to a wavelength of the light beam.

34. (Original) The micro-lens built-in VCSEL as recited in claim 24, further comprising:

a high-resistance region comprising an aperture at a center thereof through which current applied through the upper electrode flows and high-resistance region is formed by implantations of ions or by selective oxidation in a region of the upper reflector.

35. (Original) The micro-lens built-in VCSEL as recited in claim 24, wherein the lens layer comprises a thickness of several micrometers and is formed of a material having a relatively wide bandgap to a wavelength of the light beam generated from the VCSEL.

36. (Previously presented) The micro-lens built-in VCSEL as recited in claim 23, wherein the convex surface is formed by diffusion-limited etching.

37. (Original) The micro-lens built-in VCSEL as recited in claim 24, wherein the upper electrode is formed on the lens layer or between the upper reflector and the lens layer.

38. (Original) The micro-lens built-in VCSEL as recited in claim 24, wherein a distance along an optical axis from the light generating region to a vertex of the micro-lens is equal to a focal length of the micro-lens.

39. (Original) The micro-lens built in VCSEL as recited in claim 38, wherein the VCSEL satisfies a following relationship:

$$f = R \times n1/(n2 - n1)$$

where f is a distance along an optical axis from the light generating region to the vertex of the micro-lens, R is a radius of curvature of the micro-lens, $n1$ is an effective refractive index of a medium on an optical path between the light generating region and the lens layer, and $n2$ is a refractive index of a region toward which the light beam is emitted through the micro-lens.

40. (Original) The micro-lens built in VCSEL as recited in claim 38, wherein the VCSEL satisfies a following relationship:

$$n1/S1 + n2/S2 = (n2 - n1)/R$$

where S1 is a distance from the light generating region of the active layer to a vertex of the micro-lens on the optical axis, S2 is a distance from the vertex of the micro-lens to a second focal point of the micro-lens, n1 is an effective refractive index of the medium from the upper reflector and the lens layer, and n2 is a refractive index of a region toward which the light beam emitted through the micro-lens travels.

41. (Original) The micro-lens built in VCSEL as recited in claim 24, wherein as a forward biased current is applied to the micro-lens built-in VCSEL through the upper and lower electrodes, the light beam comprising a particular wavelength through laser oscillation is transmitted through the upper reflector and the lens layer and is condensed by the micro-lens and emitted as the parallel laser beam.

42. (Original) The micro-lens built in VCSEL as recited in claim 23, wherein the VCSEL is a top-emitting type VCSEL.

43. (Original) The micro-lens built-in VCSEL as recited in claim 23, further comprising:

a substrate, wherein the micro-lens is formed in the window region of the substrate through which the light beam is condensed and emitted;

a lower reflector;

an active layer comprising a light generating region;

an upper reflector comprising a higher reflectivity than that of the lower reflector;

a lower electrode formed underneath the substrate excluding a window region through which the light beam is emitted; and

an upper electrode formed on the upper reflector, wherein the window region is defined by the lower electrode and the micro-lens.

44. (Original) The micro-lens built-in VCSEL as recited in claim 43, wherein a first focal point of the micro-lens is positioned in the light generating region of the active layer, where the light beam generated in a narrow light generating region is incident on and condensed by the micro-lens, and is emitted as the parallel light beam.

45. (Original) The micro-lens built-in VCSEL as recited in claim 43, further comprising:

a high-resistance region between the upper and lower reflectors relatively close to the active layer, the high-resistance region comprising an aperture at a center thereof through which a current flows comprising a maximum width greater than or approximately equal to the maximum width of the window region.

46. (Original) The micro-lens built-in VCSEL as recited in claim 43, wherein the lower reflector, the active layer, and the upper reflector are sequentially stacked on the substrate.

47. (Original) The micro-lens built-in VCSEL as recited in claim 43, wherein when a number of stacked layers of the lower reflector is smaller than that of the upper reflector, the reflectivity of the lower reflector is lower than that of the upper reflector and most of the laser beam is emitted through the lower reflector.

48. (Original) The micro-lens built-in VCSEL as recited in claim 43, wherein the substrate is formed of a semiconductor material comprising n-doped gallium arsenide (GaAs), aluminum gallium arsenide (AlGaAs), indium arsenide (InAs), indium phosphide (InP), gallium phosphide (GaP), indium gallium phosphide (InGaP), indium gallium arsenide (InGaAs), or gallium phosphide (GaP).

49. (Original) The micro-lens built-in VCSEL as recited in claim 43, wherein the lower reflector and the upper reflector are formed of alternating semiconductor compounds comprising different refractive indexes.

50. (Original) The micro-lens built-in VCSEL as recited in claim 43, wherein the substrate comprises a material having a relatively wide bandgap compared to a wavelength of the light beam generated from the VCSEL, so as not to absorb, but transmit the laser beam incident from the lower reflector.

51. (Original) The micro-lens built in VCSEL as recited in claim 43, wherein the VCSEL satisfies a following relationship:

$$f' = R' \times n1' / (n2' - n1')$$

where R′ is a radius of curvature of the micro-lens, n1′ is a effective refractive index of a medium along an optical path between the light generating region of the active layer and the micro-lens, and n2′ is a refractive index of a region toward which the light beam emits through the micro-lens, f′ is a distance from the light generating region to a vertex of the micro-lens along the optical axis.

52. (Original) The micro-lens built in VCSEL as recited in claim 43, wherein as a forward biased current is applied to the micro-lens built-in VCSEL through the upper and lower electrodes, a laser beam comprising a particular wavelength through laser oscillation is transmitted through the lower reflector and the substrate and is condensed by the micro-lens and emitted as the parallel laser beam.

53. (Original) The micro-lens built in VCSEL as recited in claim 43, wherein the VCSEL is a bottom-emitting type VCSEL.

54. (Previously presented) The micro-lens built-in VCSEL as recited in claim 23, further comprising:

a substrate;

a lower electrode formed underneath the substrate;

a lower reflector;

an active layer comprising a light generating region; and

an upper reflector comprising a relatively lower reflectivity than that of the lower reflector, wherein the window region comprises a diameter satisfying a Fraunhofer diffraction condition and is defined by the upper electrode and the micro-lens.

55. (Original) The micro-lens built in VCSEL as recited in claim 54, wherein the window region comprises a maximum width smaller than a size of the light beam generated in the active layer emitted towards the window region.

56. (Original) The micro-lens built in VCSEL as recited in claim 54, wherein the Fraunhofer diffraction condition of the window is offset by a focusing power of the micro-lens so that a parallel laser beam is emitted through the micro-lens.

57. (Original) The micro-lens built in VCSEL as recited in claim 56, wherein the diameter D of the window and a focal length f of the micro-lens satisfy a following relationship:

$$D = \sqrt{2 \times 1.22 \lambda f}$$

where λ is a wavelength of the light beam emitted from the VCSEL.

58. (Original) The micro-lens built-in VCSEL as recited in claim 54, further comprising a high-resistance region between the upper and lower reflectors relatively close to the active layer, the high-resistance region comprises an aperture at the center thereof through which a current flows.

59. (Original) The micro-lens built in VCSEL as recited in claim 58, wherein the diameter of the window is smaller than or approximately equal to a diameter of the aperture of the high-resistance region.

60. (Original) The micro-lens built in VCSEL as recited in claim 54, wherein the window and the micro-lens are positioned on a same plane.

61. (Original) The micro-lens built in VCSEL as recited in claim 54, wherein the Fraunhofer diffraction condition satisfies a following relationship:

$$N_f = \frac{D^2}{\lambda d} << 1$$

where N_f is a Fresnel number, λ is a wavelength of the light beam emitted from the VCSEL, D is the diameter of the window, and *d* is a distance from the window to an observing plane, which is one focal point of the micro-lens.

62. (Original) The micro-lens built in VCSEL as recited in claim 54, wherein the micro-lens is positioned in front or behind the window or the micro-lens and the window are positioned on a same plane.

63. (Original) The micro-lens built in VCSEL as recited in claim 54, wherein when the micro-lens and the window are positioned on a same plane and only a 0^{th}-order diffracted beam comprising a high intensity is considered, a radius R_s of the 0^{th}-order diffracted beam satisfies a following relationship:

$$R_s = \frac{1.22\lambda d}{D}$$

where λ is a wavelength of the light beam emitted from the VCSEL, D is the diameter of the window, and d is a distance from the window to an observing plane.

64. (Original) The micro-lens built in VCSEL as recited in claim 54, wherein the VCSEL is a top-emitting type VCSEL.